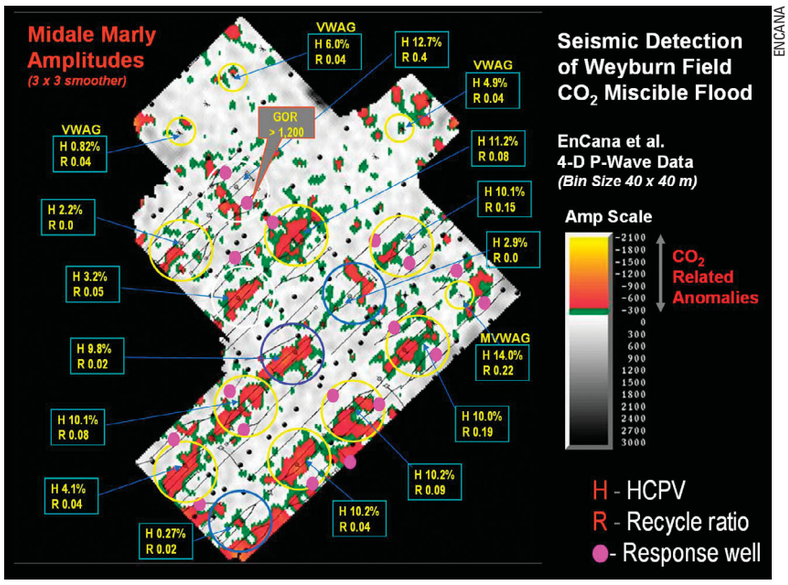
Demonstrating carbon sequestration

Initial findings from the largest carbon sequestration project in North America show that the oil industry can cost-effectively recycle waste carbon dioxide (CO_2) gas to recover petroleum from underground reserves at the end of their productive life span. Although the industry has used CO_2 in this manner for 40 years, this is the first major project to recycle waste gas from another energy source, pioneering the process that experts expect to become the main route for carbon sequestration in the future.

The Weyburn CO_2 Monitoring and Storage project now under way in Canada's Saskatchewan province involves pumping waste CO_2 gas from the Dakota Gasification Co. in Beulah, N.D., up over the U.S.–Canadian border to the Weyburn oil field through a 320-kilometer pipeline. John Gale, program manager for geological storage at the International Energy Agency's Greenhouse Gas R&D Programme (IEA GHG) in Cheltenham, England, calls the project "a very close second" in importance to the Sleipner project run by Statoil in Norway, where waste CO_2 from natural gas is being injected into deep saline aquifers on the sea floor (*Environ. Sci. Technol.* **1999**, *33*, 66A–70A).

The Weyburn site is notable for using waste CO_2 gas rather than tapping into naturally occurring CO_2 from underground reservoirs, which is how the oil industry historically harvested the gas to help capture the last remaining oil in underground deposits, says Howard Herzog of the Massachusetts Institute of Technology, who is leading his university's Carbon Sequestration Initiative. The traditional approach actually "unsequesters" carbon, he explains.

The Weyburn project is expected to sequester 14 million metric tons (t) of CO_2 during its lifetime—about 77% of the gas pumped into the reservoir. The 1 million t of CO_2 captured per year are equivalent to the amount generated by a 150-megawatt coal-fired power plant, says Scott Clara of the U.S. Department of Energy's (DOE) Office of Coal and Environmental Systems. The CO_2 is injected into the oil field through 29 injection wells, and there are 4 observation wells in the area. Funding for the project comes from 20 international organizations, including IEA; DOE; the European Community; and 7 industrial sponsors from Canada, the United States, and Japan.



The Weyburn researchers are using 4-D seismic surveys, such as this one, to infer the movement of the CO_2 injected into the underground reservoir.

There are a growing number of geologic carbon sequestration projects around the world, but the Weyburn project is one of only four large, long-term active or planned projects that will sequester 1 million t of CO_2 annually, points out Herzog. In addition to Weyburn and Sleipner, Statoil is planning a second project in Norway and British Petroleum has one planned in Algeria.

The other three large projects involve sequestering the waste CO_2 that is routinely separated from natural gas to make it burn more efficiently. Rather than following the traditional approach of venting the unwanted carbon into the atmosphere, Statoil is injecting the waste gas into underground reservoirs, Herzog says.

Herzog argues that because the oil industry always makes an effort to use some kind of technology to enhance oil recovery at the end of its wells' life spans, projects like Weyburn offer some of the best opportunities for scientists to study the value of geologic sequestration. The injection is taking place already and therefore scientists must simply monitor it more extensively, rather than having to drill a network of injection wells (*Environ. Sci. Technol.* **2001,** *35,* 148A–153A).

Another advantage of Weyburn, say scientists, is that the Saskatchewan province's records on the geophysical, production, and injection activities in the oil field are among the most extensive available. The project's organizers are using 4-D seismic technology to

map the movement of the injected CO_2 through the underground reservoir, which helps scientists determine how much of the sequestered CO_2 stays underground (*Environ. Sci. Technol.* **1999**, *33*, 66A–70A). By showing how the CO_2 moves through the reservoir, the 4-D technology is helping researchers determine if they can direct CO_2 storage, explains Koorosh Asghari, an assistant professor of petroleum systems engineering with the University of Regina.

IEA GHG estimates that 120 gigatons of CO_2 could be stored in depleted oil fields, approximately 13% of the total set forth by the Kyoto Protocol to stabilize emissions at 550 parts per million, Gale says. However, he says that the figure may be pessimistic because it is based on the assumption that 50% of the CO_2 injected into an underground reservoir stays there. Studies conducted to date show that the amount varies based on the miscibility of the CO_2 in petroleum, but anywhere from 33 to 50% of the gas may be taken up by the oil it is used to recover, Gale says. However, the oil industry has good technologies for separating this CO_2 from the oil pumped out of the wells, Asghari says.

It is too early to calculate the percentage of CO_2 being permanently sequestered at Weyburn, but the seismic studies are showing that the CO_2 is not escaping from the underground formation, says Mike Monea, the project's executive director at the Petroleum Technology Research Centre in Regina, Saskatchewan. Observers are concerned about the possibility that CO_2 will migrate up through wells or casings that have been bored into the rock. "I'm not worried about that…if we in the oil industry know anything, it's how to plug holes," Monea says.

"The only way to breach this reservoir is with fractures," Monea notes. The project's scientists are currently using models to calculate how much CO_2 could escape through fractures in the rocks over the next 5000 years.

Monea is particularly pleased because the project is thus far recovering significantly more oil from the Weyburn field than the 15% improvement predicted with modeling. "We have seen a 25% increase in oil production…of 5000 more barrels of oil per day," Monea says. He expects that the project will prove profitable.

Gale agrees that the project will be a moneymaker, but he points out that the cost of the CO_2 used in the project is relatively low. Asghari says that Dakota Gasification is charging $1/t. The cost of collecting CO_2 is generally $35/t, Gale explains. However, Dakota Gasification had already constructed equipment for capturing the gas, so it can still make a profit. DOE's goal is to reduce the cost of collecting CO_2 to $10/t within the next few decades.

The cost of capturing CO_2 needs to come down before energy companies will be able to cost-effectively collect it from major sources like power plants, Herzog says. But IEA GHG has identified more than 200 plants, like Dakota Gasification, at which CO_2 is present as a high-purity gas and could be captured and transferred to nearby oil fields to help enhance oil recovery, Gale says. In addition, the operators of some of the other oil fields in the vicinity of Weyburn could be interested in buying Dakota Gasification's waste gas to increase their oil production, he adds.

The first official progress report on the Weyburn project is due out early next year. —KELLYN BETTS